Voith Hydro
Hydro Power Plants

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AGCS, Munich

Voith in figures

In over 50 countries

42,000 Employees

5 Markets

R&D ratio

4.7 %

Family-owned since

1867

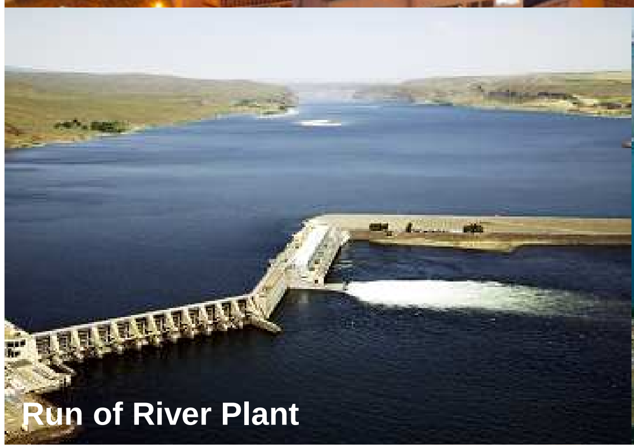
Sales

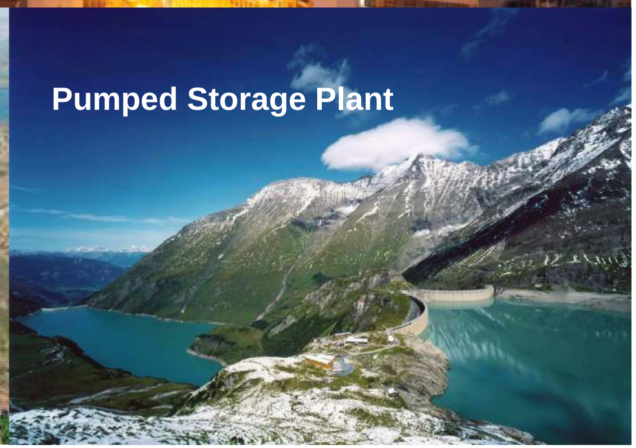
€5.7 billion

Stand: 2011/12

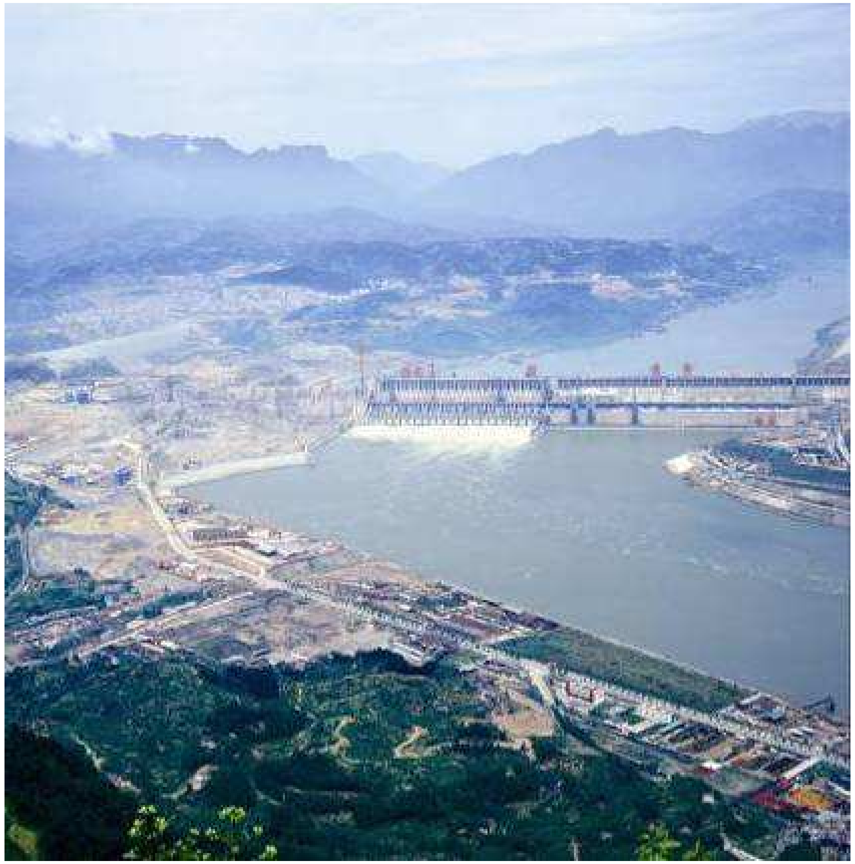
Energy

A quarter of all electricity generated by hydro power worldwide is produced with technologies and services from Voith.





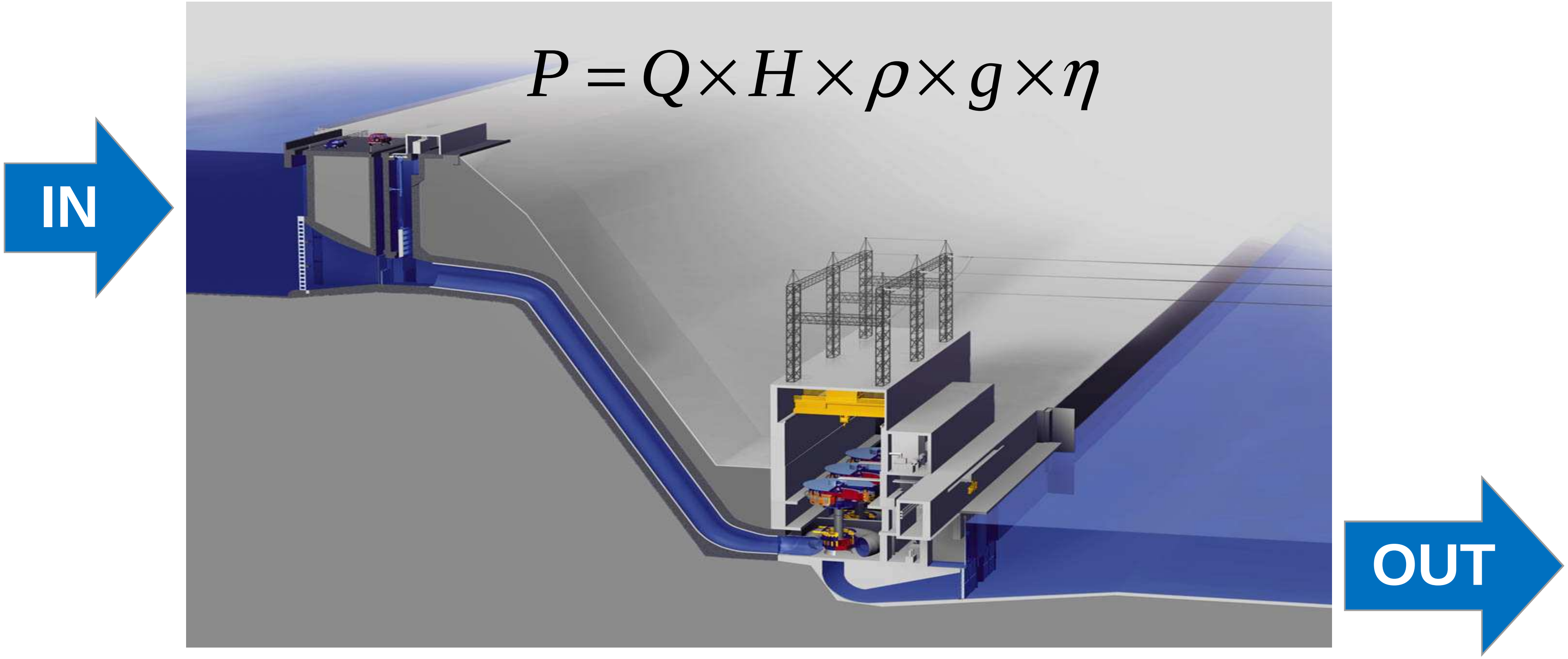
140 Years of Major Projects



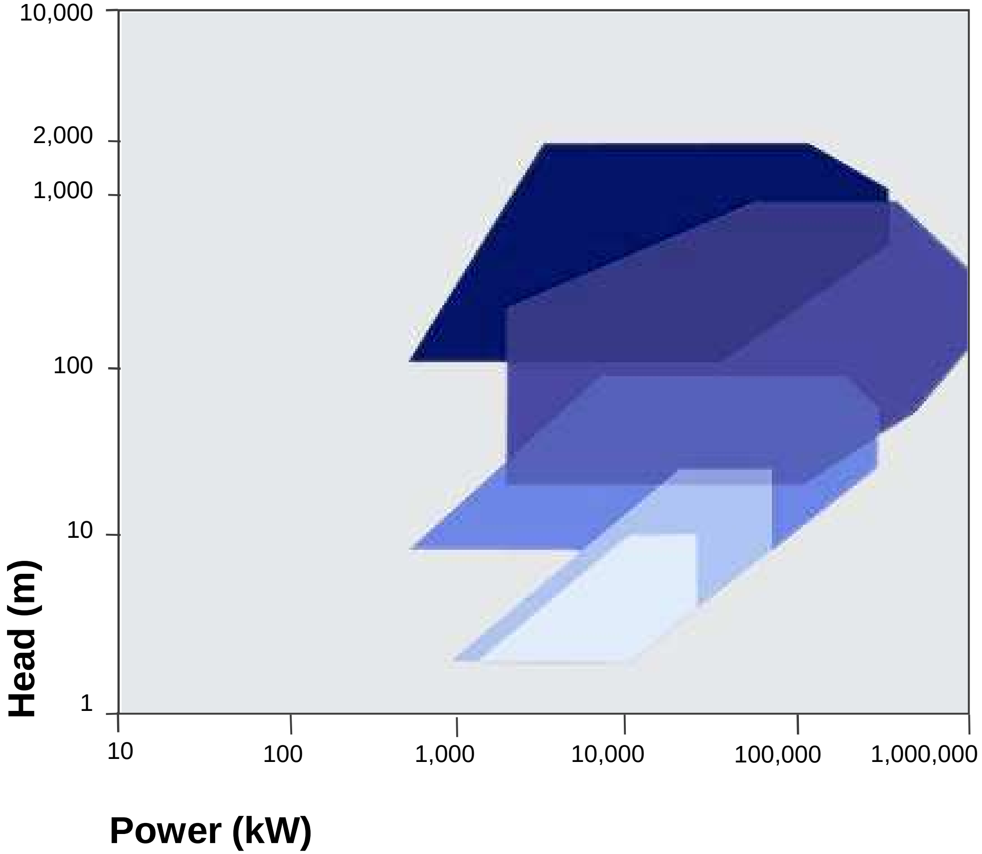
1873	First Voith Francis turbine
1903	First Pelton turbine
1912	Niagara Falls, Canada
1934	Pedreira, Brazil
1938	Sungari, China
1964	Roenkhausen, Germany
1970	Raccoon Mountain, USA
1995	First fish-friendly turbine design
1997	Three Gorges, China
1998	Goldisthal, Germany
2000	Guangzhou II, China
2010	Frades II, Portugal
2011	Belo Monte, Brazil

Flow Q and Head H are decisive for the power

$$P = Q \times H \times \rho \times g \times \eta$$



Head H is mainly influencing the turbine type



Pelton:

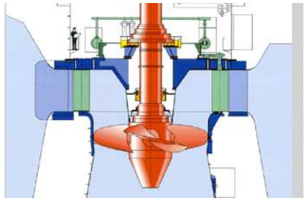
~200m to 2.000m

Francis

~50m to ~700m

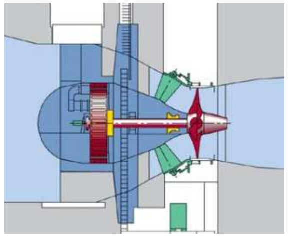
Kaplan

~2m to ~50m



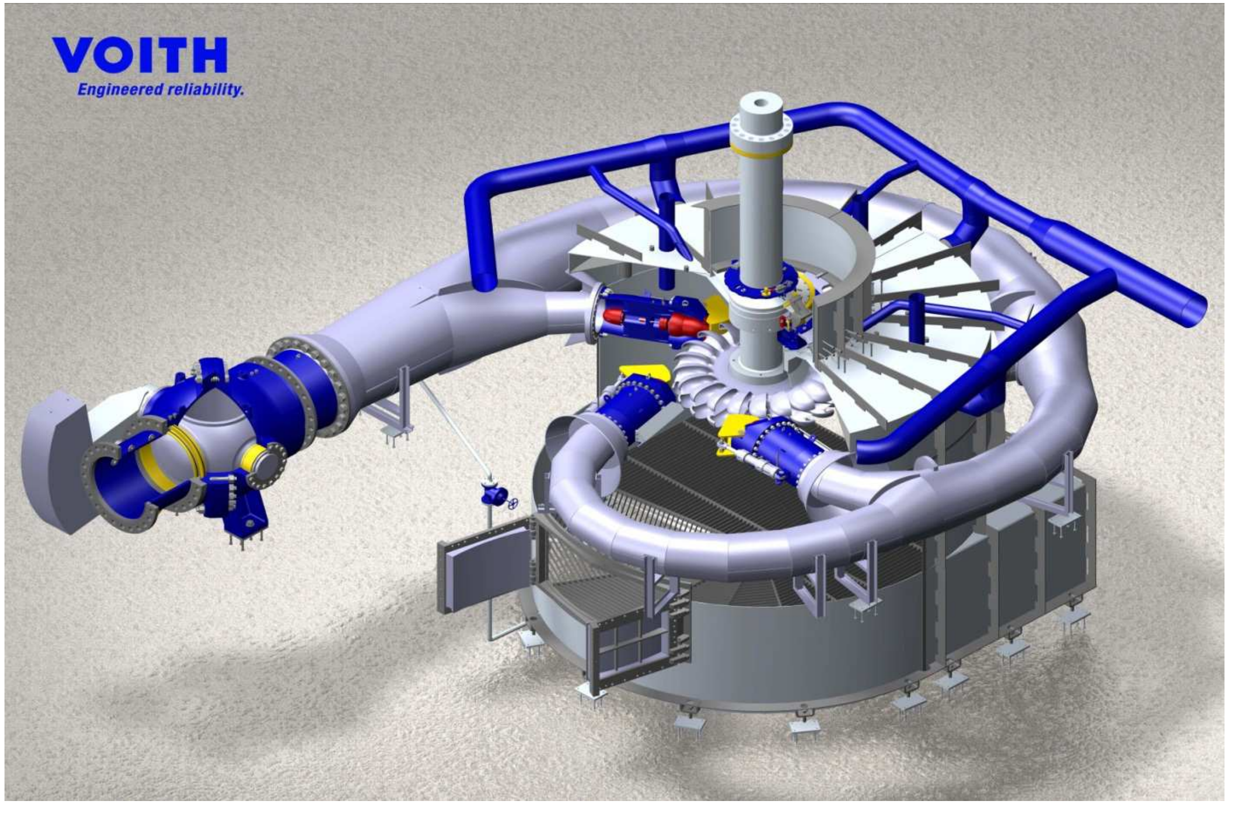
Bulb

~2m to ~20m



Pit ~2m to ~10m

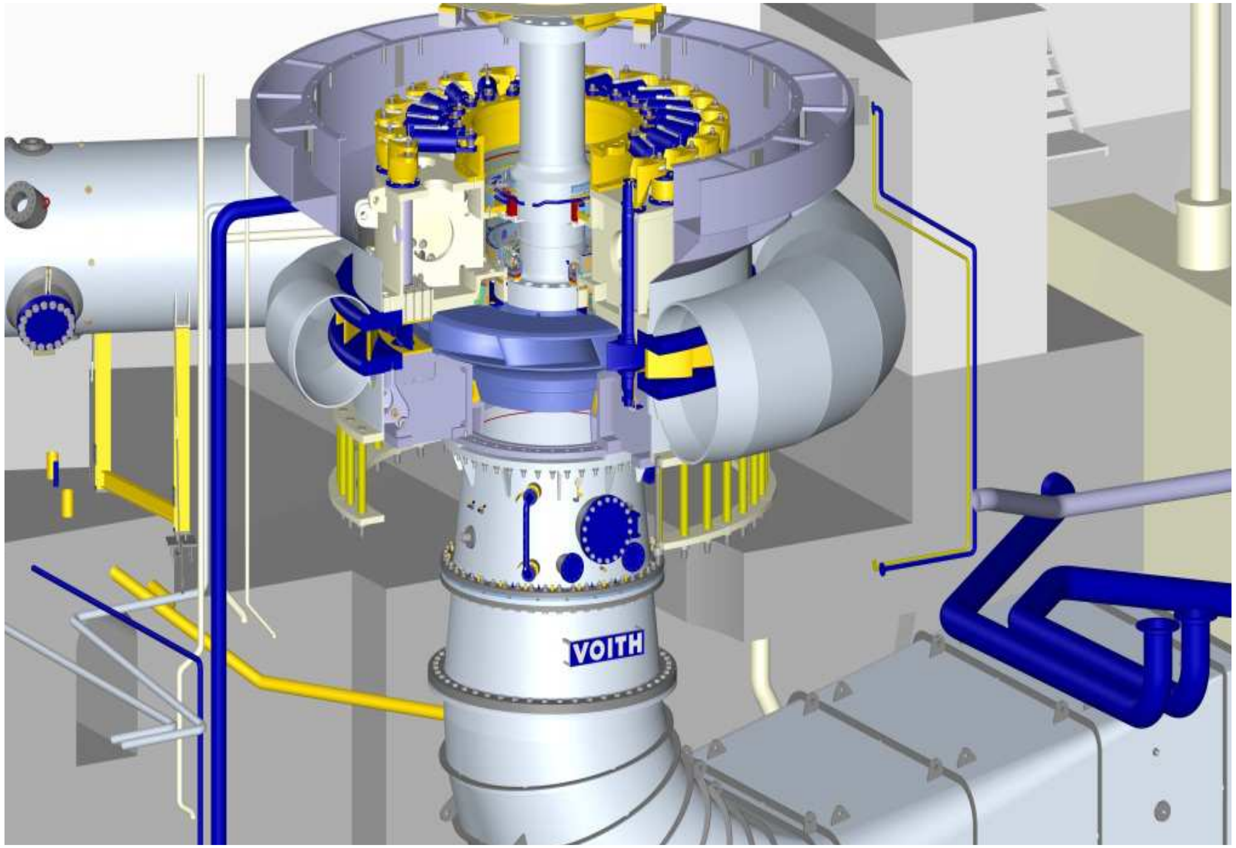
Head H is mainly influencing the turbine type



Pelton

~200 m to 2,000 m

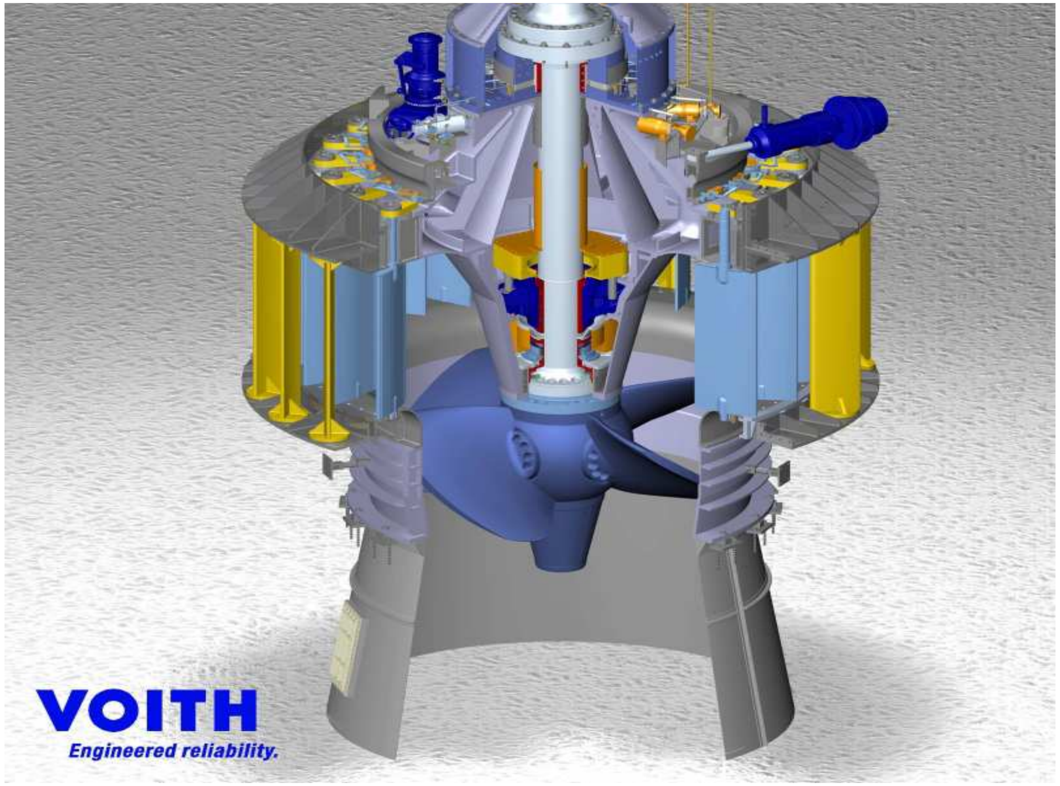
Head H is mainly influencing the turbine type



Francis (pump turbine)

~50 m to 700 m

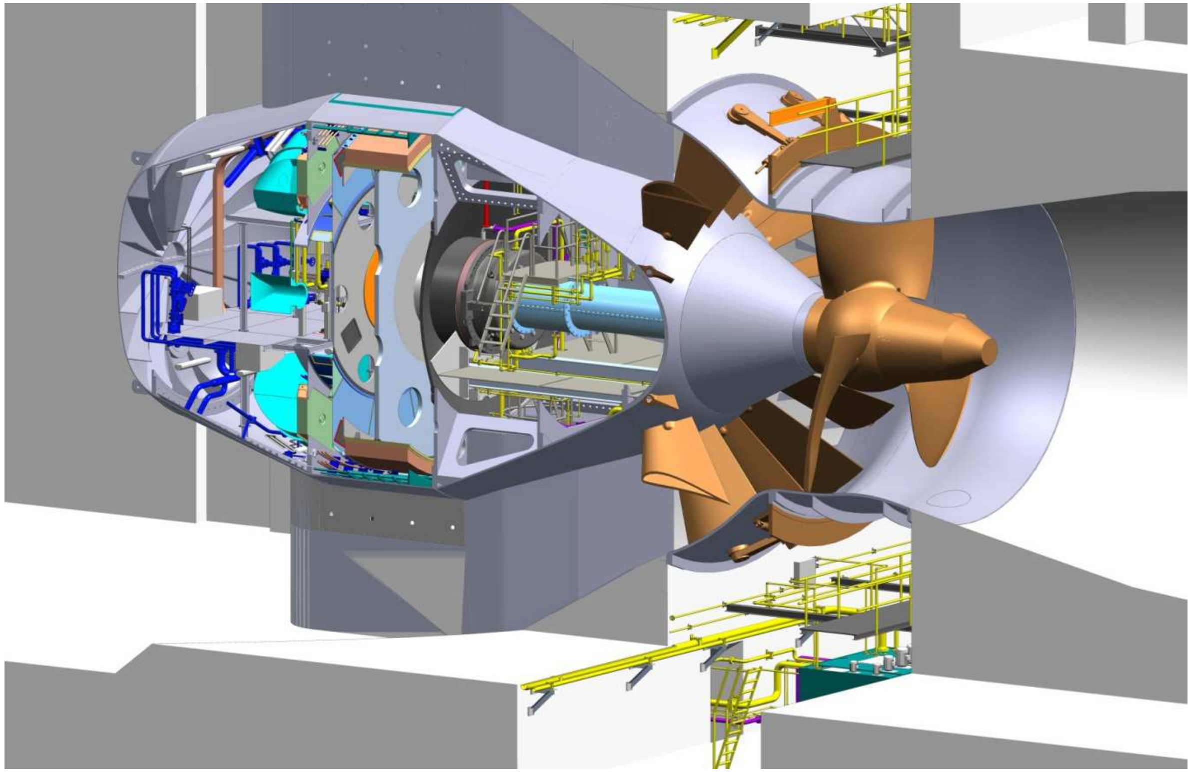
Head H is mainly influencing the turbine type



Kaplan

~2 m to 50 m

Head H is mainly influencing the turbine type



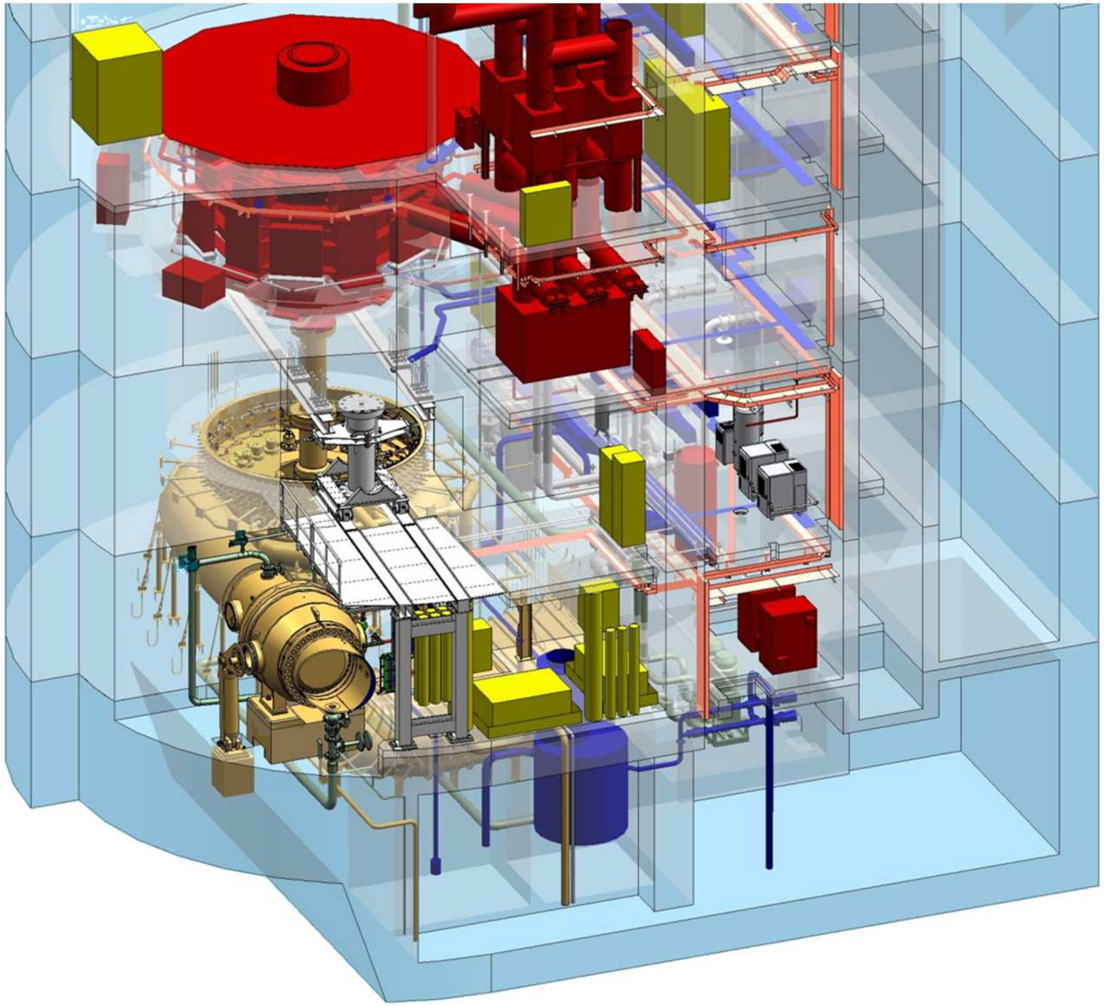
Ohio River. Cannelton, USA

Bulb

~2 m to 20 m

Complete Plant Systems

Pump Storage Powerhouse using full 3D CAD Capabilities



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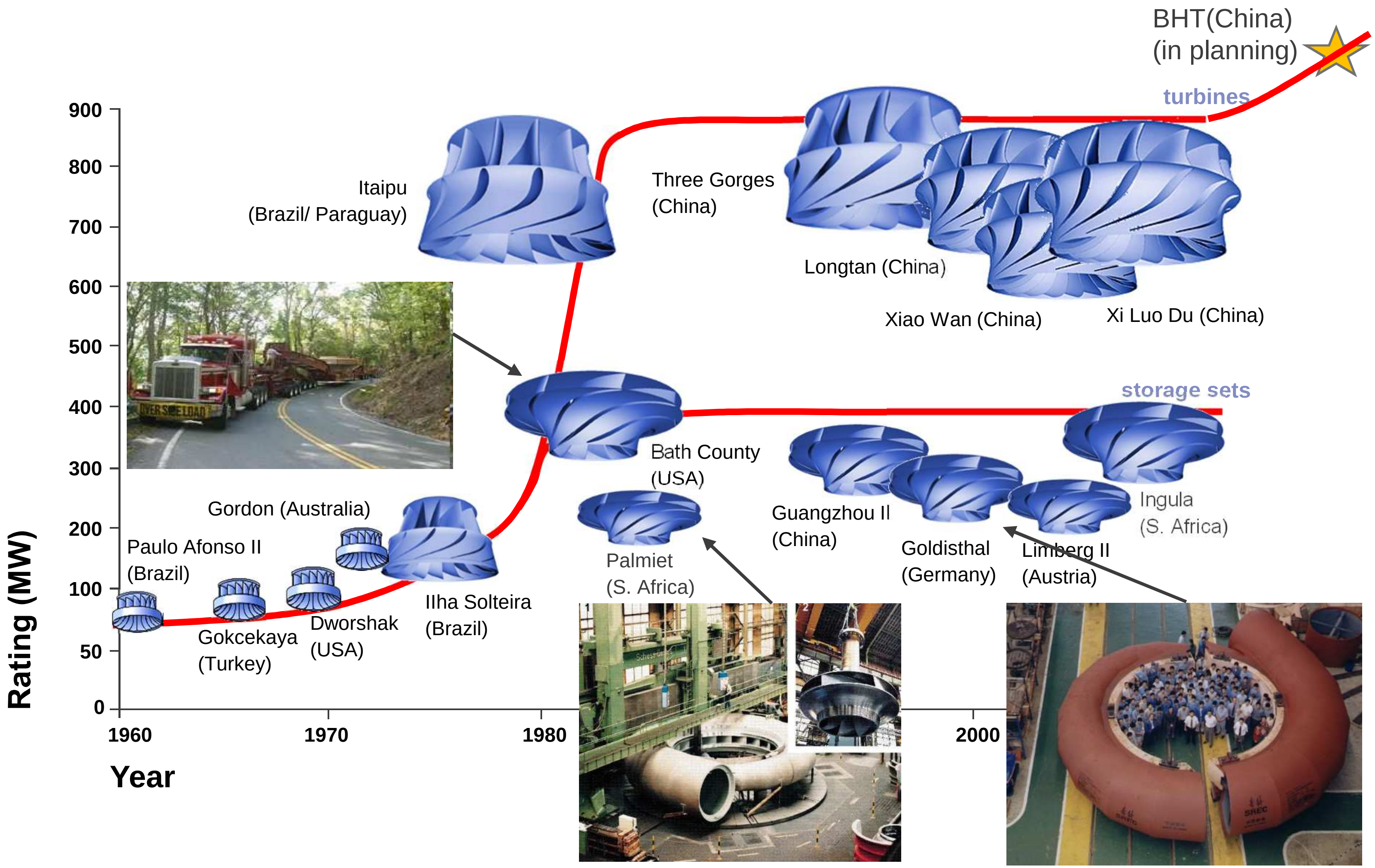
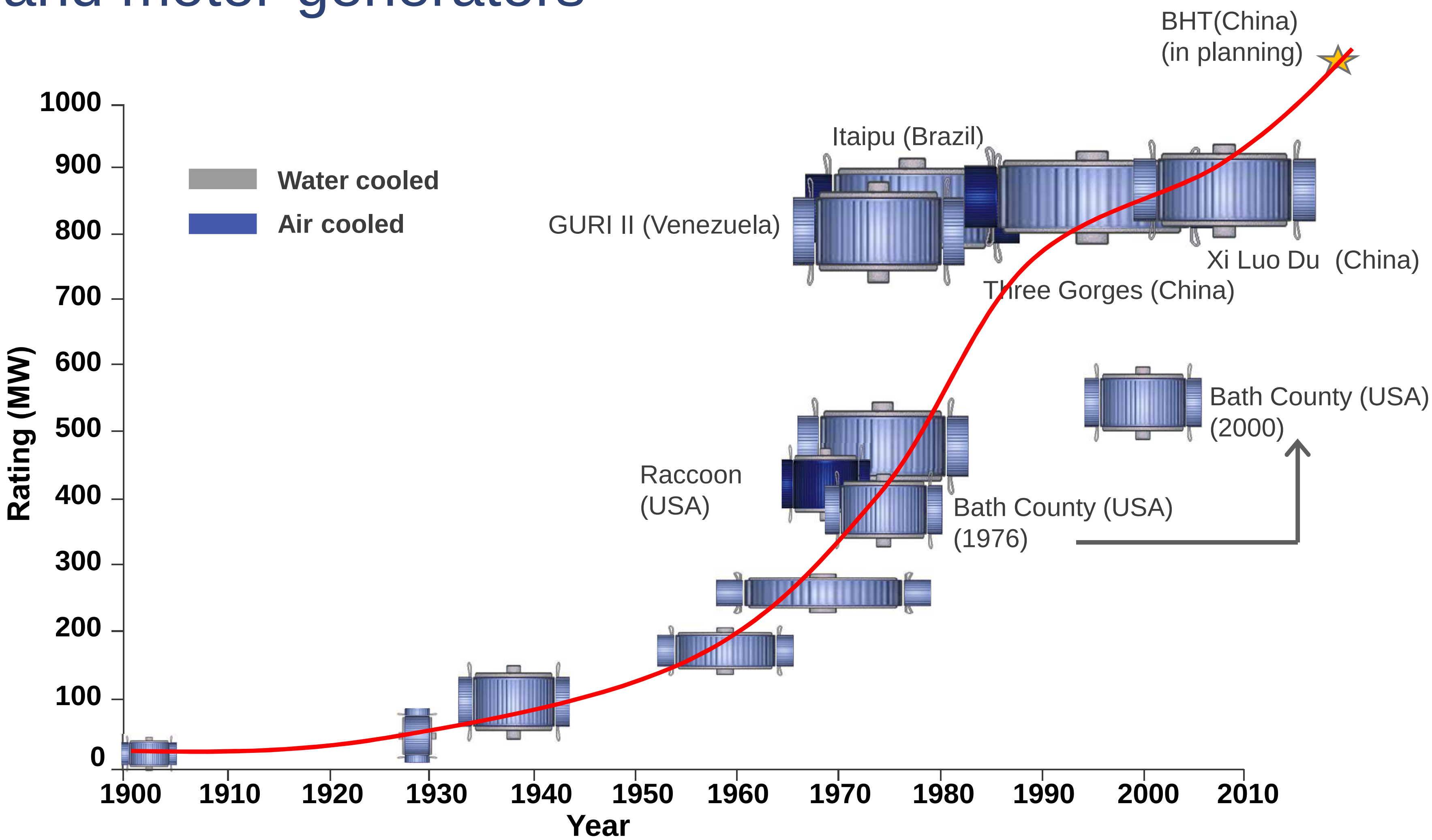
History of hydro power turbines and pump-turbines



History of hydro power generators and motor-generators



Logistic Challenge:
400t Stainless Steel Runner

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Rotor Assembly – Precision with > 2000t

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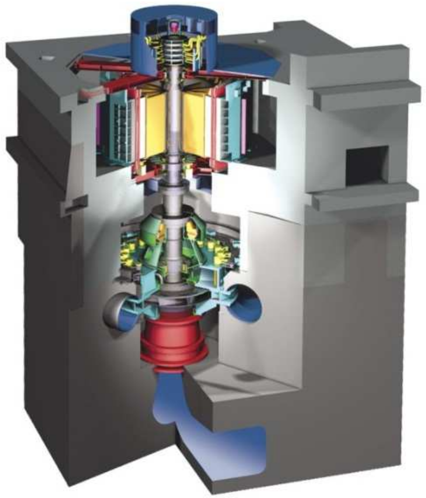
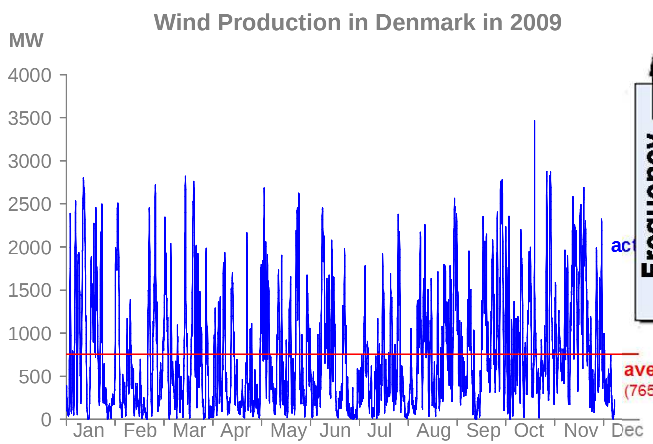
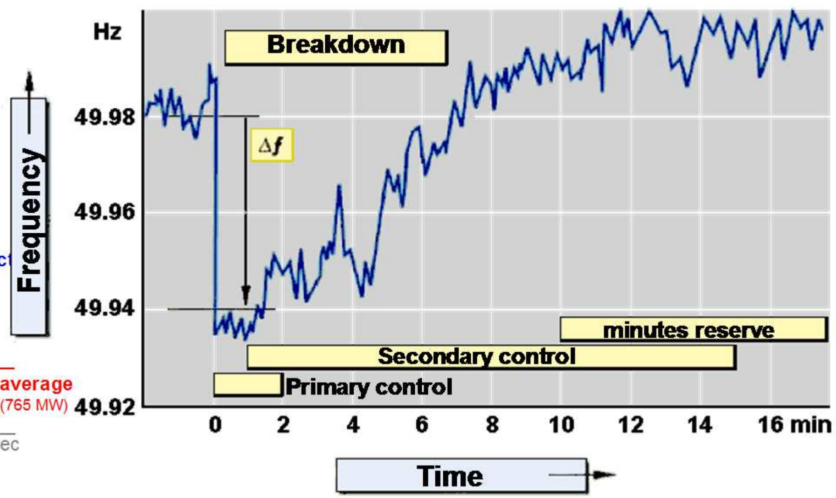
Pumped Storage

- **Wind, Solar and Hydro Integration**
  - Reserves
  - Frequency regulation







Energy **Frequency** **Storage**

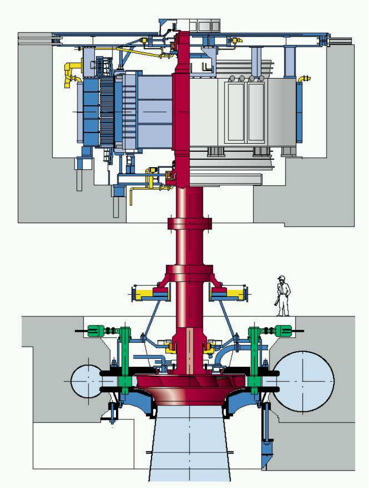
Major pumped storage projects of Voith Hydro

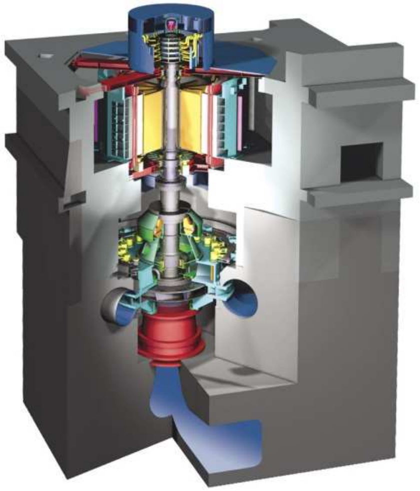
Possible Unit Configurations Depending on Regulation Responsiveness and Grid Needs

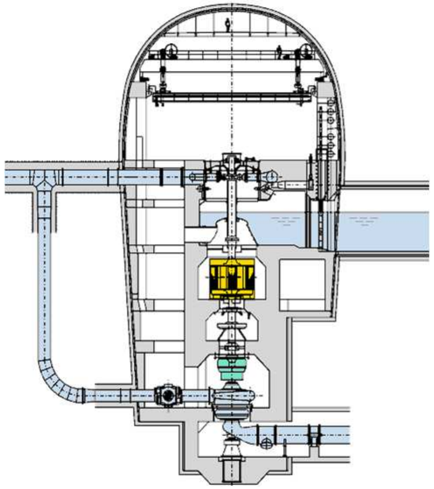
- Conventional reversible unit
- Fast & frequent response reversible unit
- Conventional units in short circuit arrangement
- Variable Speed reversible unit
- Ternary unit arrangement

Slower
Less Flexible

Faster
More Flexible







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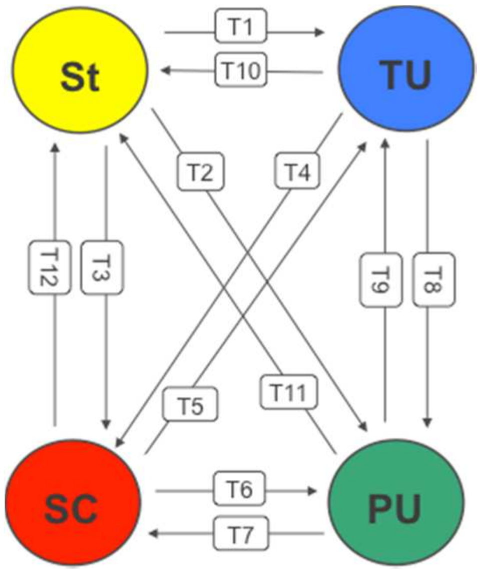
Mode change times for various Unit concepts - "Flexibility"



T	Pump Turbine Mode change			A	B	C	D	E
				time [seconds]				
1	Standstill	→	TU-Mode	90	75	90	90	65
2	Standstill	→	PU-Mode	340	160	230	85	80
5	SC-Mode	→	TU-Mode	70	20	60	40	20
6	SC-Mode	→	PU-Mode	70	50	70	30	25
8	TU-Mode	→	PU-Mode	420		470	45	25
9	PU-Mode	→	TU-Mode	190	90	280	60	25

Reversible PT

A – advanced conventional

B – extra fast response conventional

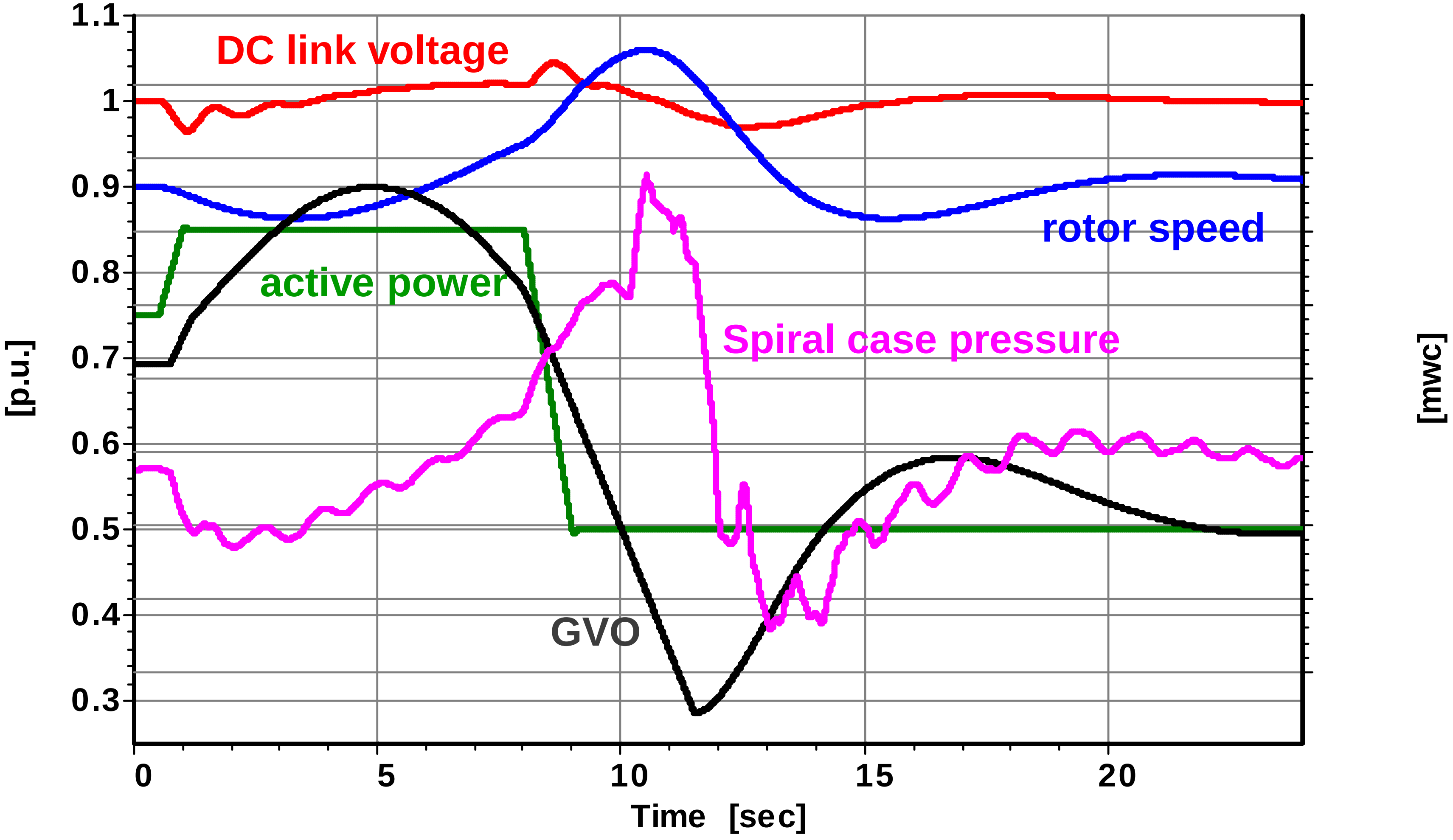
C – VarSpeed,

Ternary set

D – with hydraulic torque converter + hydr. short circuit, horiz, with Francis Turbine

E – same as E but vertical with Pelton Turbine

Fast control of var. speed units
Effect on water hammer



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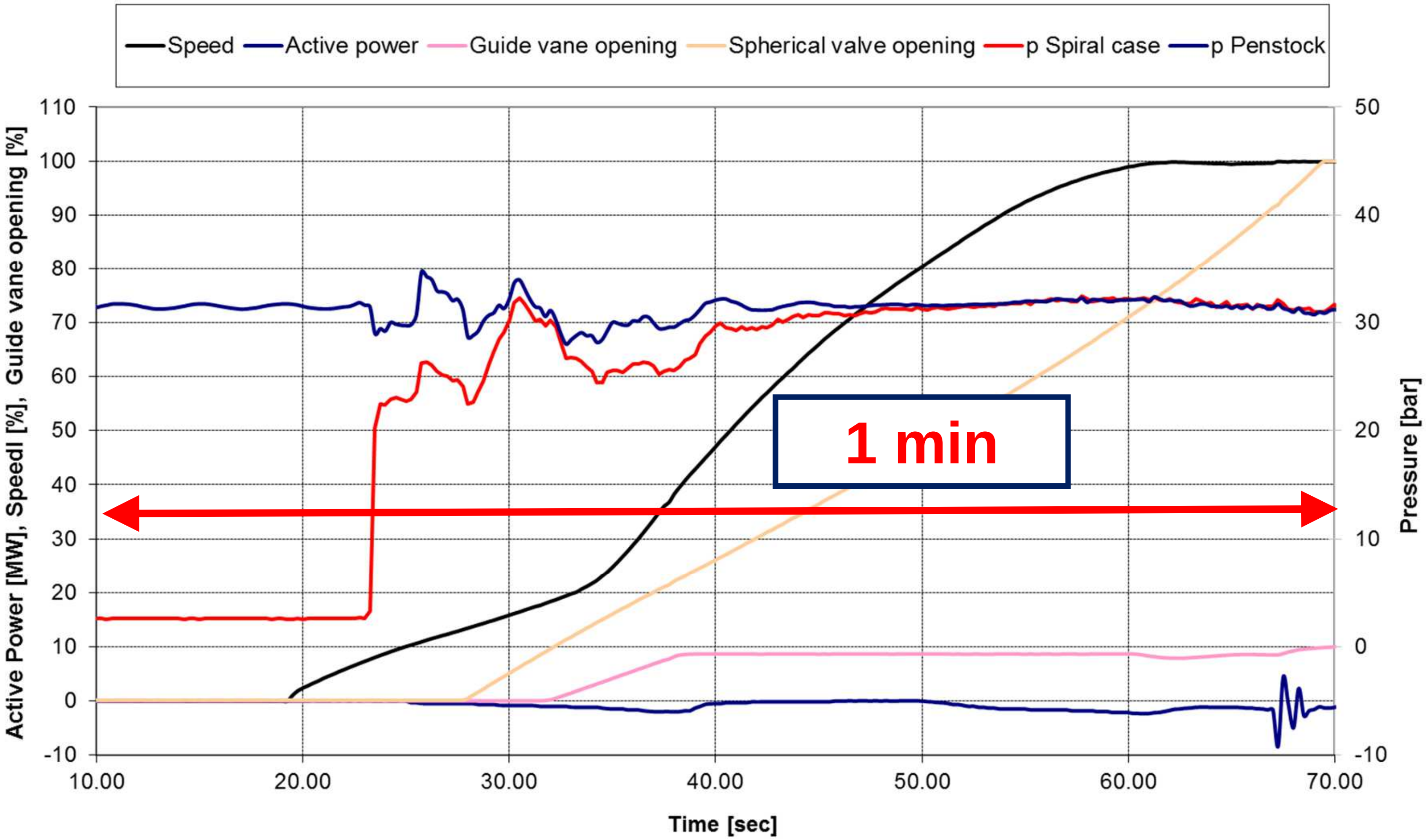
Start up – Pump Turbine



Ancillary Services of Conventional and Pumped Storage Power Plants

- Frequency regulation
- Voltage / Power Factor control
- Load Following
- Reduced system minimum loading (i.e. many base load units run below minimum load; resulting inefficiency and voltage & frequency problems)
- Black Start capability
- Regulation Up (in the generating direction)
- Fast Regulation Up & Down with variable speed pumped storage power plants (in the generating and pumping directions)

The Voith Hydro Policy for Plant Operational Safety

Objective and goals

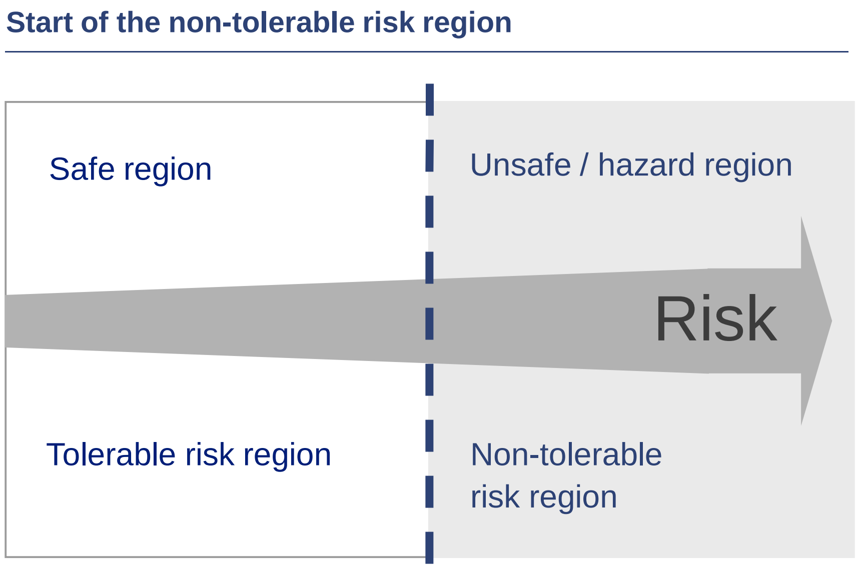
The Voith Hydro Safety Policy is deduced from the idea of Engineered reliability.

The goal of this policy in Voith Hydro is to sustain highest protection of:

- Human lives
- Environment
- The capital investment of our customers



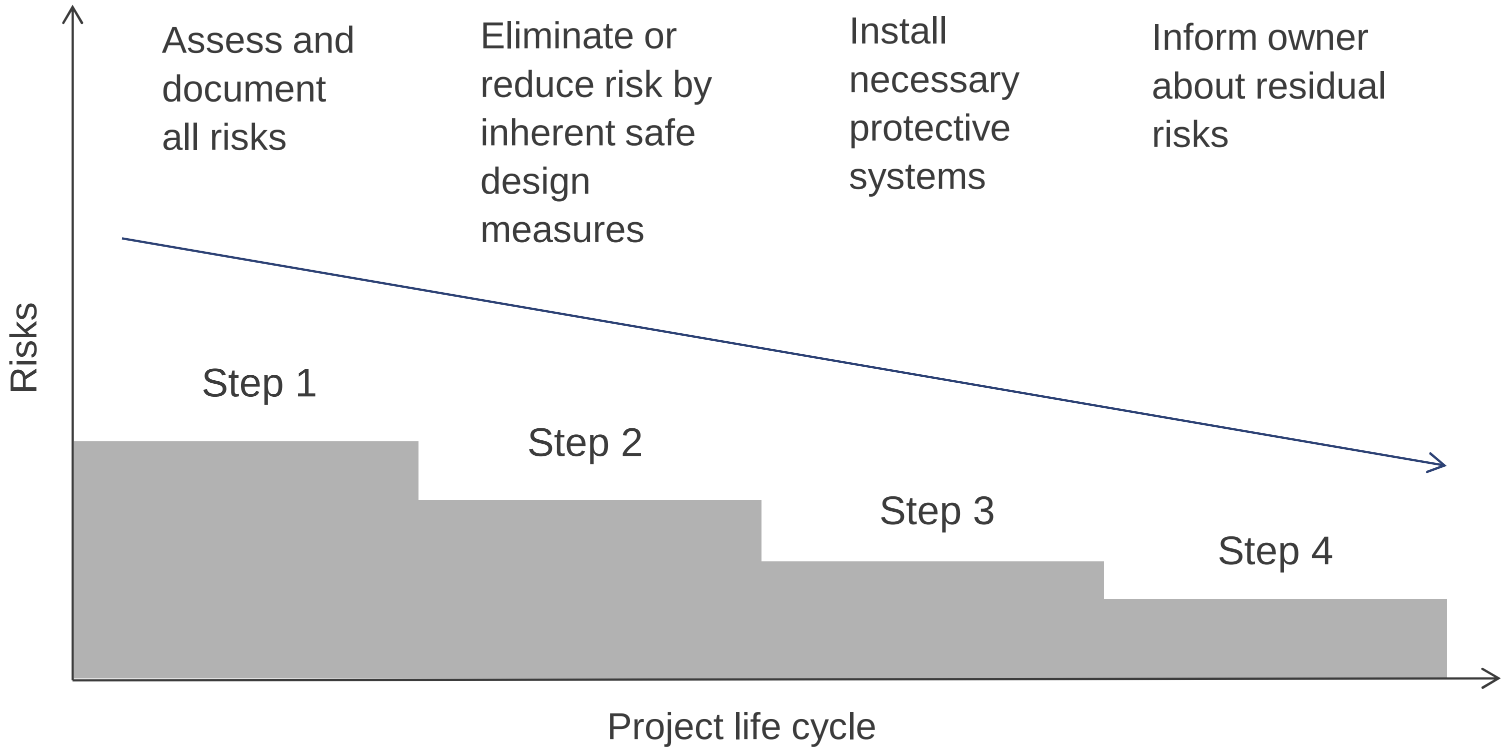
Basic philosophy



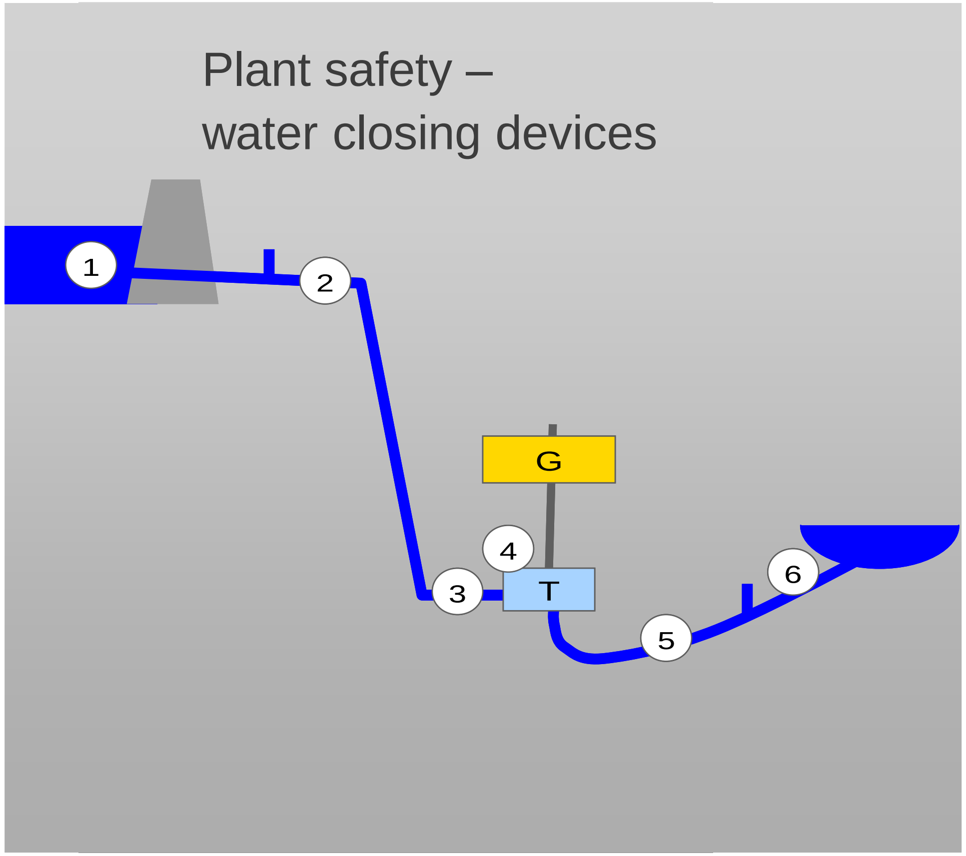
One major failure tolerant in areas with high energy flow or where the loss of protection is not acceptable.

Voith Hydro requires for emergency situations and/or in case of failure of one safety element a second countermeasure.

Risk reduction process



Hydro power plant – water ways



1. Gate or roller stop log
2. Gate or butterfly valve
3. Butterfly valve or spherical valve
4. Distributor or nozzles
5. Gate or stop log or butterfly valve
6. Gate or stop log

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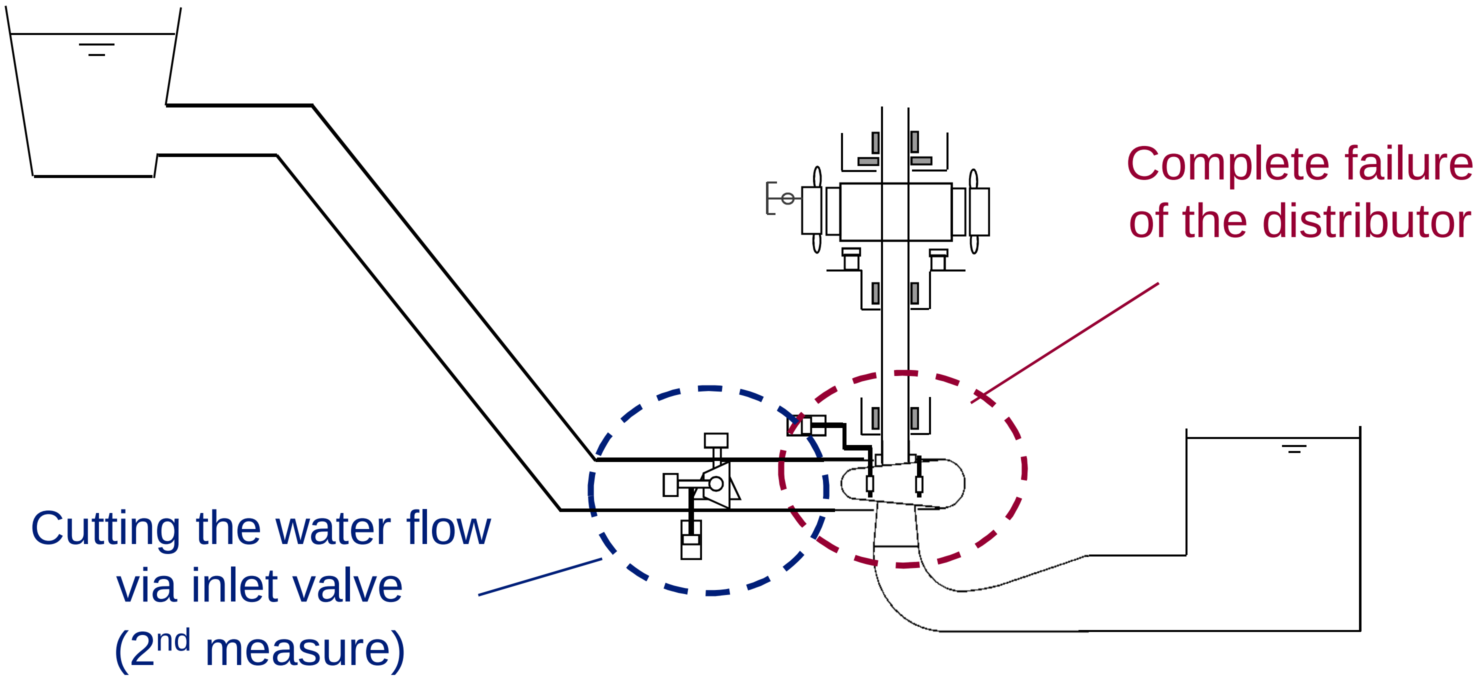
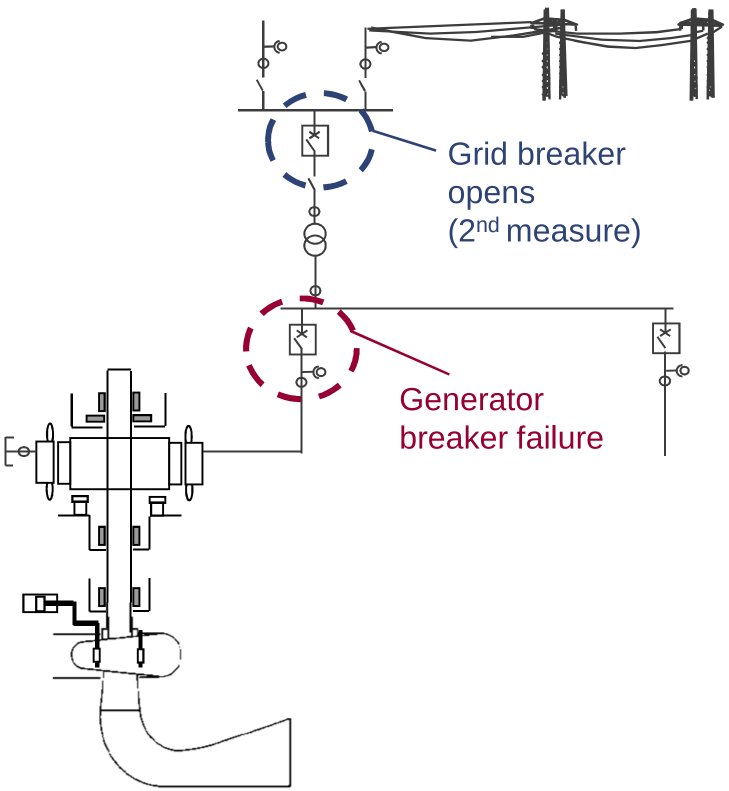
Hydro power plant

Example of 1 major failure tolerance in the water ways.
→ Minimum requirement of two closing devices.



Hydro power plant



Example of 1 major failure tolerance in the power train.

→ Minimum requirement of two circuit breaker levels, for interrupting each current -even in short circuit condition.

Example of penstock buckling

Safety Policy requires redundant aeration valves or natural aeration for the penstock.

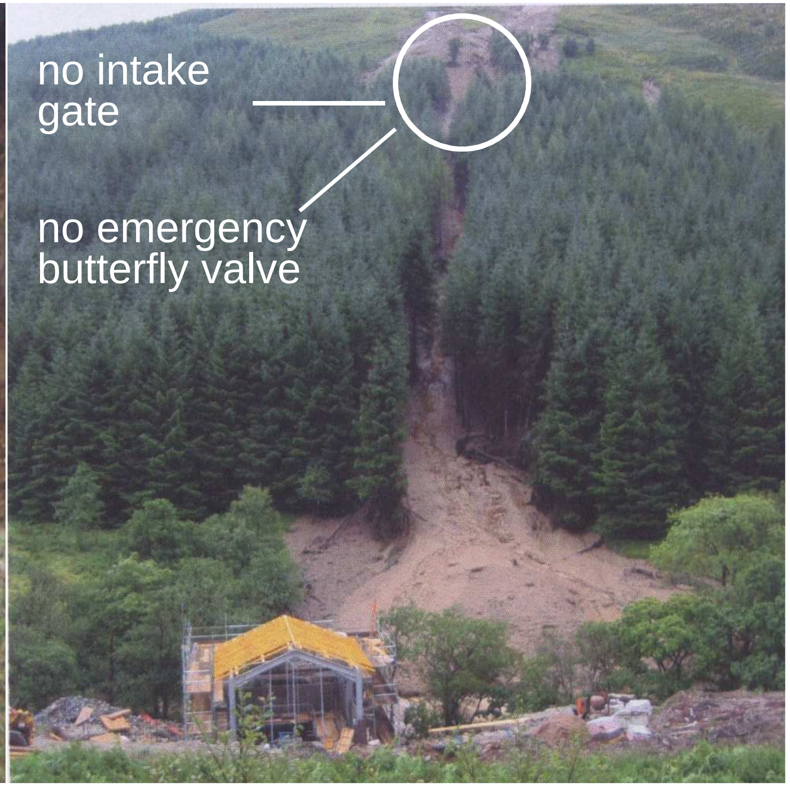
After a penstock pressure test the valve for the penstock dewatering has been opened. Either the aeration valve was not able to open or it was too small designed.

The same accident happens, if an emergency valve in the upstream section closes and the aeration valve does not open.

Source: From a publication of Vattenfall Europe (former HEW): „Strom vom Strom – 40 Jahre Pumpspeicherwerk Geesthacht“.

Basic philosophy

VH requires in special cases also a mitigation system in order to limit the damage extent. Penstock rupture and landslide in Scotland.



Voith Hydro Safety Policy

Our Safety Policy is a crucial element in the supply of our products to owners and operators. Highest reliability and safety of our equipment safeguard capital investment of owners on a long-term basis and sustain the balance of state-of-the art technological standards with highest demands in this area. Technological, economical, environmental and social responsibility are incorporated in our values of engineered reliability.

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Engineered Reliability